Soil Fertility and Fertilizers
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Lecture 05
Importance of Soil Nutrient Management and Basic Soil Plant Relationship

Welcome friends to this fifth and final lecture of week one of NPTEL online certification course of Soil Fertility and Fertilizers. And in this week we are talking about importance of soil nutrient management and basic soil plant relationship.

So in the previous lectures we have discussed the basic concepts of plant nutrition we have discussed about the essentiality criteria we have classified the nutrient based on their essentiality. And also we have seen some important rules we have seen the basic overview of plant nutrition we have seen the soil fertility indicators.

And also we have seen we have discussed some important mechanisms of nutrient uptake by the plants like active transport passive transport. And also we have seen different types of the use of the carrier proteins. There are different types of active transport and also we have seen the contact exchange and their related theories.

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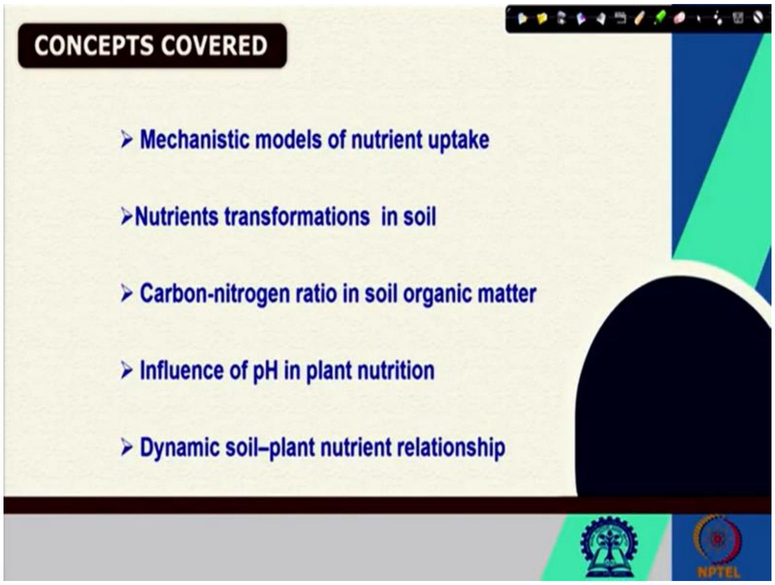

So in this lecture we are going to discuss this following concept of mechanistic model of nutrient uptake. We are also going to discuss the nutrient transformation in the soil we are going to discuss the carbon nitrogen ratio in soil organic matter, influence of ph in plant nutrition and finally we are going to discuss the dynamic soil plant nutrient relationship.

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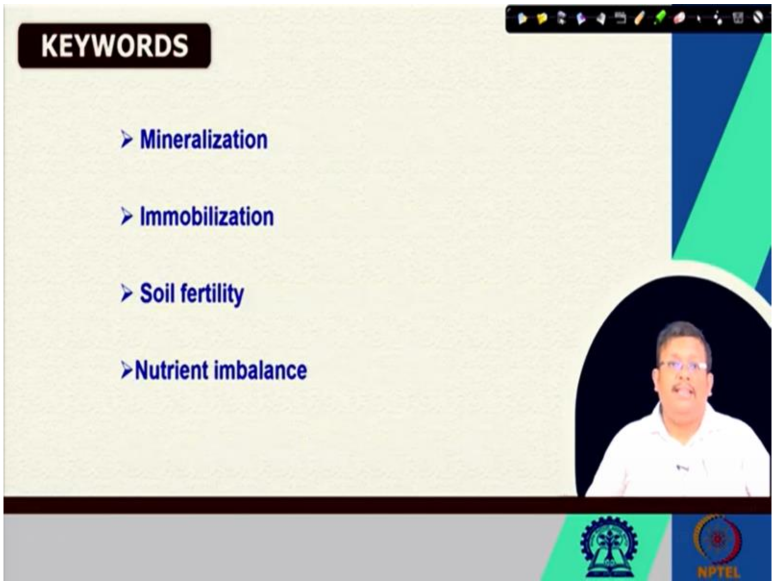

So these are some of the major concepts which we are going to cover in this lecture. And these are some of the keywords in this lecture mineralization, immobilization, soil fertility and nutrient imbalance.

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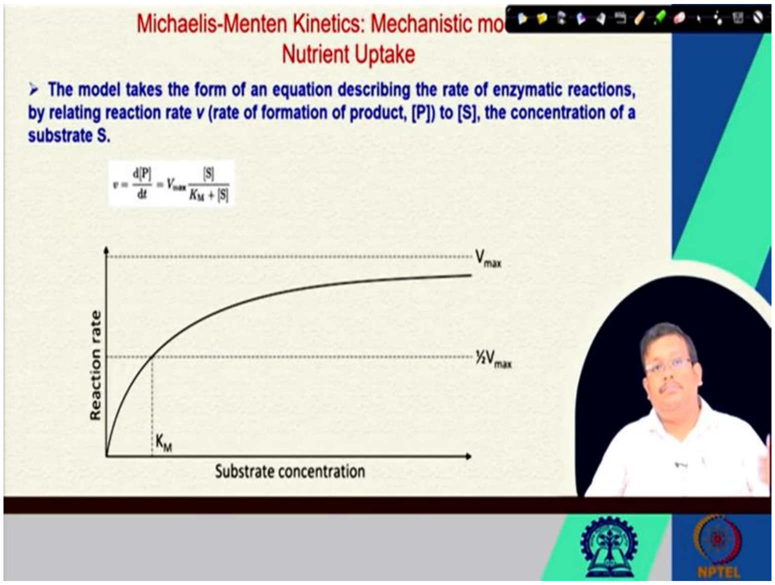

So let us start with a Michaelis-Menten kinetics. So it is basically in it is a model which is generally widely used in enzyme kinetics however for mechanistic models of nutrient uptake we are also we generally we also use this Michaelis-Menten kinetics. But before that let us first see what is Michaelis-Menten kinetics.

So this Michaelis-Menten model basically takes the form of an equation describing the rate of enzymatic reactions by relating reaction rate which is denoted by v that is a rate of formation of product which is denoted by this p and to s which is the concentration of a substrate s. So the equation shows the small v is basically d p by d t equal to v max multiplied by substrate by k m plus substrate so this k m is basically also known as the Michaelis-Menten kinetics.

So graphically if we see in the x axis we are putting the substrate concentration in the y axis we are putting the reaction rate. So as the substrate concentration is increasing we are seeing the increase in the reaction rate. And this midpoint is known as midpoint of this reaction rate is known as half of v max and this is also known as the so using this formula also we can we can express the nutrient uptake in the plant. And here k m stands for the Michaelis-Menten coefficient.

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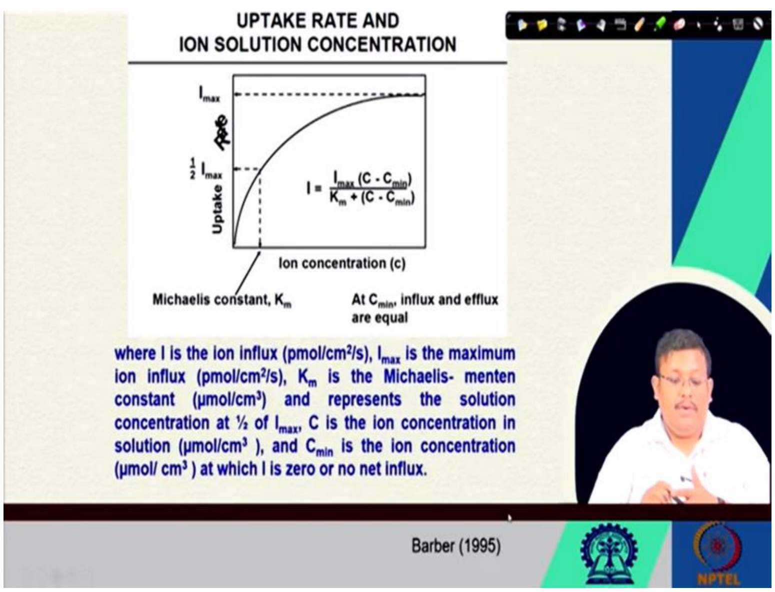

So based on this equation, based on this relationship, so based on this relationship we can see that uptake rate and plant uptake rate and iron solution concentration can on also be connected together. So we can see here that in the x axis we are putting the ion concentration which we denote by c and the uptake which we generally indicate by I so the maximum take which is called the I max and half of this maximum uptake is half of I max.

So here this Michaelis-Menten or Michaelis constant is again just like in the previous slide we have seen that ion concentration which will be required to get the half of maximum uptake is known as this Michaelis constant just like we have seen in our previous slide. And that in flux I stands for influx or uptake and if flux means release. So here I or influx of ions can be related by this equation that is I max equal to I max multiplied by c minus c min or minimum concentration by k m plus c minus c min.

So where I is the ion influx and I max is the maximum ion influx k m is the Michaelis-Menten constant and represents the solution concentration at half of I max just like I have told you and c is the ion concentration in solution and c mean is the ion concentration at which I is 0 or no net influx. So the ion uptake and ion concentration can be related by assuming the same relationship as we have seen in case of Michaelis-Menten kinetic describing the enzymes. So this mechanistic model of nutrient uptake can be realized by assuming the Michaelis-Menten kinetics.

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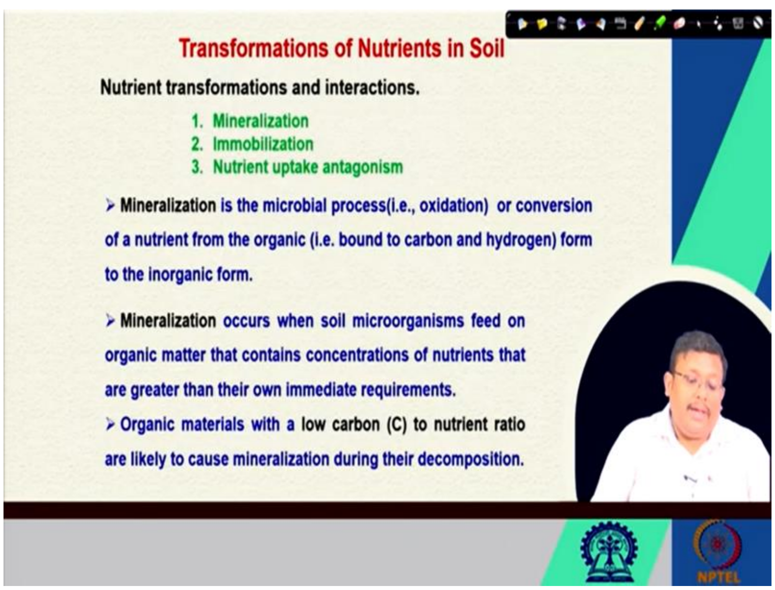

Now let us move ahead, let us now see what are the major processes to which the nutrient transforms in soil. So nutrient transformation and interaction can be discussed in terms of three major mechanisms one is mineralization second is immobilization third one is nutrient uptake antagonism. So mineralization is the microbial process or is an oxidation process also it is basically conversion of nutrient from organic form to inorganic form.

Mineralization generally occurs when soil microorganisms feed on organic matter that contains concentration of nutrients that are greater than their own immediate requirements. Of course when the nutrient content is higher than their own immediate requirement then only those nutrients are going to convert and they are going to be present in the soil in inorganic form. So this process is known as mineralization process.

Generally organic materials with a low carbon to nutrient ratio are likely to cause mineralization during the decomposition process. We will see in our coming slides that this c n ratio or carbon to nitrogen ratio plays an important role in this nutrient mineralization process. Because when the carbon to nitrogen ratio is less that means the nutrient content is quite high and that means there will be surplus amount of nutrient after they are being utilized by the microorganisms in the soil. And they will be released in the soil environment as inorganic nutrients so this is known as the mineralization process.

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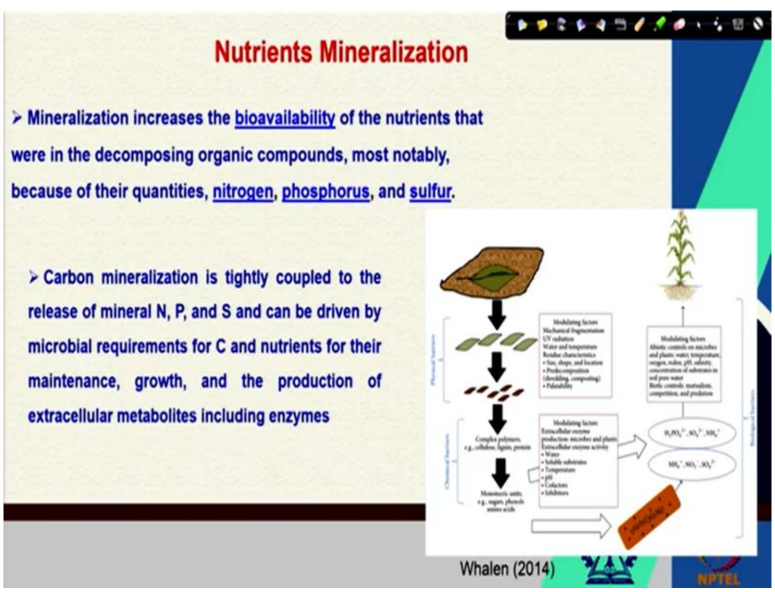

Now mineralization increases the bioavailability of the nutrients that were in decomposition that were in the decomposing organic compounds and most notably because of their quantities nitrogen phosphorous and Sulphur. So through mineralization process nitrogen phosphorus and sulfur are become more bioavailable and carbon mineralization is tightly coupled to the release of mineral nitrogen phosphorus and sulfur and can be driven by microbial requirements for carbon and nutrients for their maintenance growth and the production of extracellular metabolites including enzymes.

Now here you can see that these when there is a leaf fall it will go through different types of processes through which this mineralization ultimately results in the formation of these ammonium nitrate sulphate and orthophosphata and cell and so these are again being uptaken by the plant. So there are different types of factors modulating factors which governs this mineralization process. So we are going to discuss all these in our coming slides.

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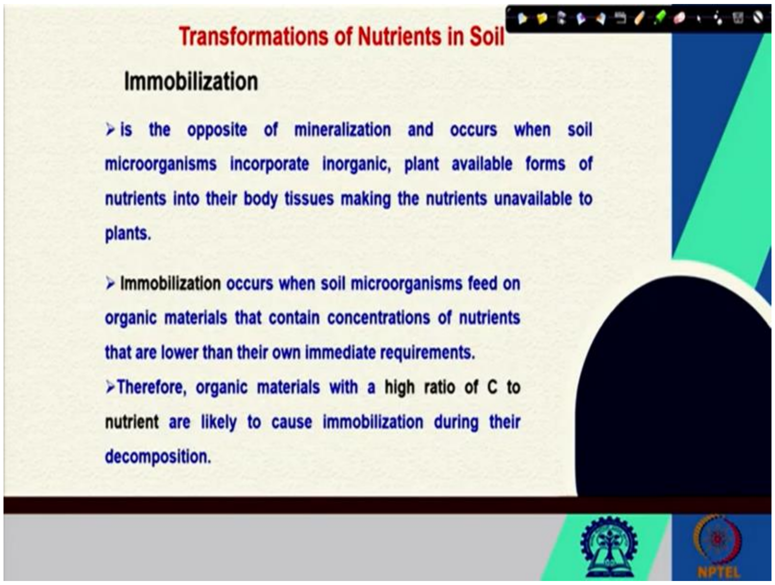

Now another process is known as immobilization process. Now this immobilization is just opposite to mineralization in case of mineralization we remember that there is a conversion of organic form to inorganic form however in case of immobilization there is a conversion from inorganic form of the nutrients to organic form of nutrients.

Now in case of immobilization the microorganisms incorporate the inorganic plant available forms of the nutrients into their body tissues making the nutrients unavailable to the plants. And immobilization occurs when soil microorganisms feed on organic materials that contain concentration of nutrient that are lower than their own immediate requirement.

Therefore, the organic materials with a high c or c 2 9 nutrient ratio are likely to cause immobilization during the decomposition. We are going to see in our coming slide that the materials with high cn ratio is generally much more liable to the immobilization process. So again where the mineralization is the conversion of organic form of nutrient to inorganic form of nutrient immobilization is just opposite that is conversion of inorganic form of nutrient to organic form of nutrient.

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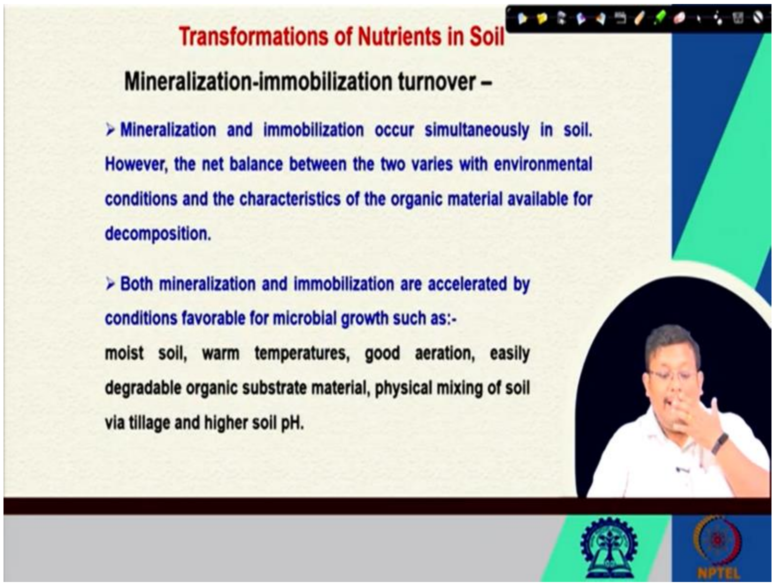

So now let us see what is mineralization immobilization turnover. So mineralization and immobilization occurs simultaneously in the soil, however the net balance between the two processes varies with environmental conditions and the characteristics of the organic material available for decomposition.

Both mineralization and immobilization are accelerated by conditions favorable for microbial growth such as moist soil warm temperature good addition easily degradable organic substrate material substrate material physical mixing of soil via tillage and higher soil ph. So when there is a moist soil that will favor the growth of the microorganisms also warm climate will also warm temperatures will also favors the growth of the microorganism growed aeration will help to boost their activity.

Easily degradable organic substrate material substrate material will act as their energy source. Physical mixing of soil via tillage will incorporate more amount of air and more amount of organic material to the soil. And higher soil ph will also encourage the activities of different microflora and microphone. So that is why the mineralization and immobilization occurs simultaneously and the relative dominance of one mechanism depends on the situation that prevails at that at the time in the soil environment.

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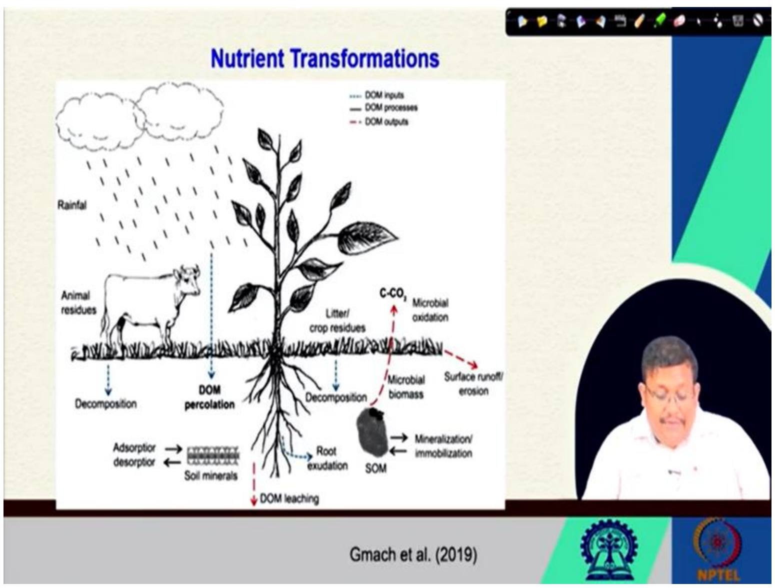

Now if you see the nutrient transformation this picture gives you a overall view of nutrient transformation of course you can see when there are liters or crop residues that will go through decomposition process.

And through the decomposition process there will be a release of carbon dioxide and this and also there will be root exudation and there will be addition of dissolve organic matter through the rainfall and animal residues will also go through decomposition process. And these nutrients will either goes through the adsorption and desorption process in the soil minerals.

And the soil organic matter again goes through the mineralization immobilization and when there is a decomposition of organic of crop residues they will release this carbon dioxide and .

And which will be results of microbial oxidation and these nutrients will also go through surface runoff for erosion.

So here in this dashed line you can see the dissolve organic matter inputs and also these dissolve organic matter outputs you can see in this red arrows. So these nutrients which are there in this different animal residues and plant residues they will do different types of transformation based on this mineralization immobilization they are also supposed to leach down due to the high amount leads down to the to the to the lower layers of the soil.

And the nutrients which are bound to this organic matter will either absorb or dissolve from the soil minerals. So these are some of the transformation of nutrients in the soil.

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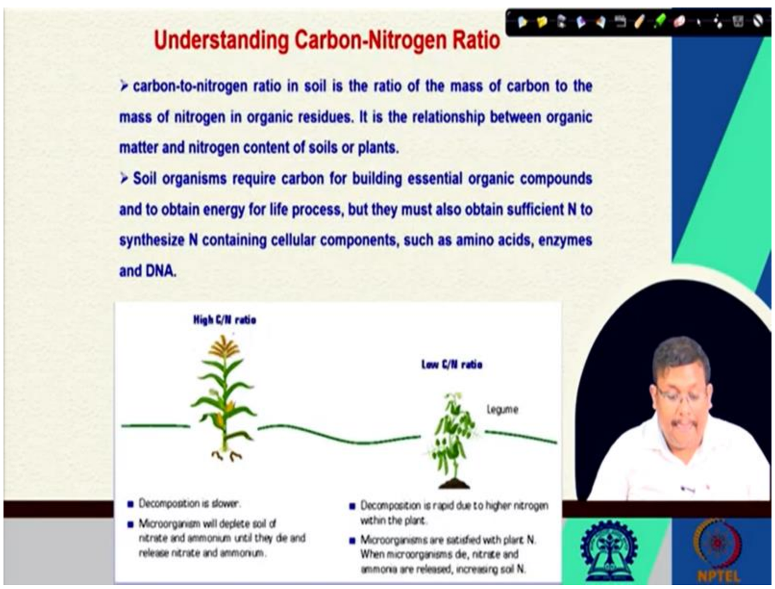

Now let us see the carbon nitrogen ratio. Now carbon to nitrogen ratio in soil is the ratio of the mass to carbon mass of carbon to the mass of nitrogen in organic residues. It is the relationship between organic matter nitrogen content of soil or plants. Now soil organisms require carbon for building essential organic compounds and to obtain energy for life processes.

But they must also obtain sufficient nitrogen to synthesize nitrogen containing cellular components such as amino acids enzymes and DNA. So here you can see the corn crop is growing on the soil with high carbon to nitrogen ratio and here legume is growing in the soil with low carbon to nitrogen ratio. Of course when the carbon to nitrogen ratio is high the decomposition will be lower because decomposition will be slower because the microorganisms activity will be decreased.

So microorganisms will deplete soil of nitrate and ammonium until they die and release nitrate and ammonium. And in case of low carbon to nitrogen ratio decomposition is rapid due to higher nitrogen within the plant. And microorganisms are satisfied with plant nitrogen when microorganism die nitrate and ammonia are released increasing soil nitrogen. So these are the implication of height cn ratio and low cn ratio.

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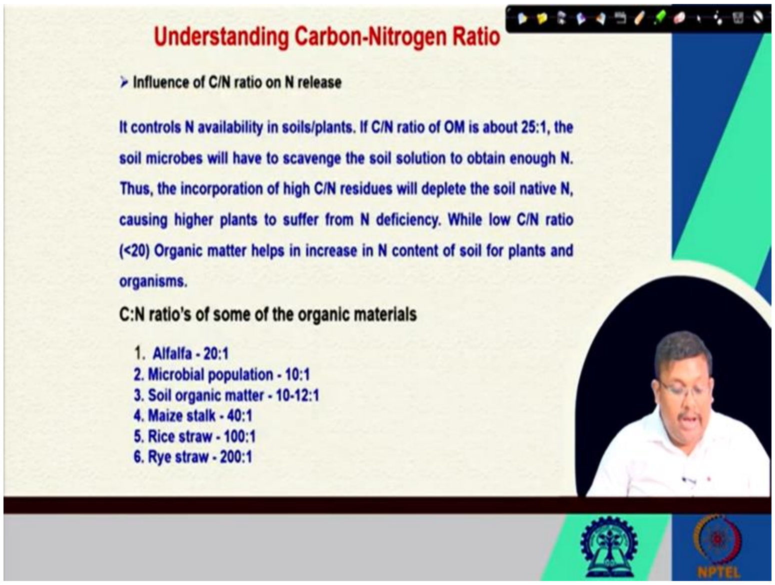

Now influence let us see what are the influence of carbon to nitrogen ratio on nitrogen release. Now it controls the nitrogen availability in the soil and plants if C/N ratio of organic matter is greater than is above is about 20 25 is to one then the soil microbes will have to scavenge the soil solution to obtain the enough nitrogen. Thus the incorporation of high cn residues will deplete the soil native nitrogen.

So in the absence of enough amount of nitrogen these microorganisms will uptake the nutrients from the solution so there will be depletion of nitro native nitrogen causing higher plants to suffer from nitrogen deficiency. While low cn ratio which is less than 20 organic matter helps in increase in nitrogen content of the soil for plant and organism.

So let us see some c n ratio of some of the organic materials like alpha alpha twenties to one microbial population ten is to one soil organic matter ten to twelve is to one main stock forty to one rice store hundred is to one and rice draw two hundred is to one.

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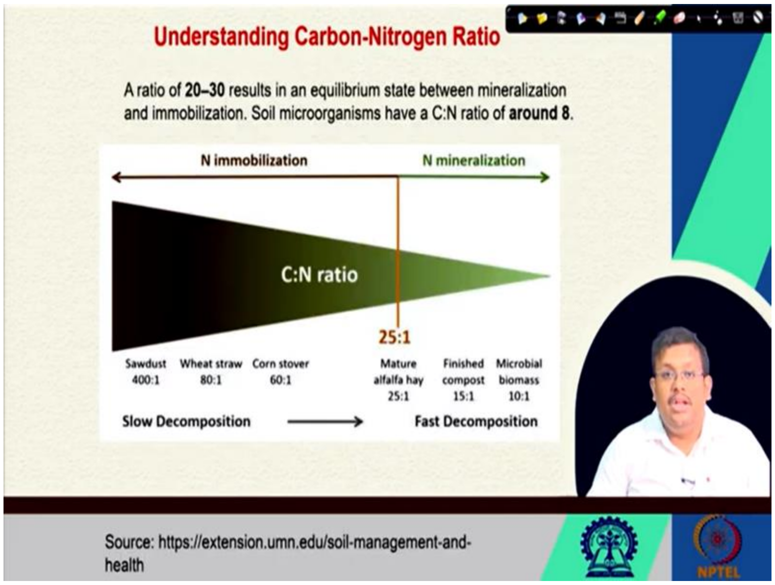

So here we can see here a ratio of twenty to thirty results in an equilibrium state between the mineralization and immobilization and soil micro organisms have and c n ratio of around eight. So here you can see when the c n ratio is quite high that will results in nitrogen immobilization and nitrogen mineralization generally occurs when the cn ratio is low.

So there is a threshold limit we can see here which is around 25 is to one which is also the c n ratio of a mature alpha alpha hay. And when we go for the finished compost it is 15 is to one in case of microbial biomass it is 10 is to one so that results in fast decomposition. However when the cn ratio is quite low that is sawdust with straw and const over that increases the nitrogen immobilization.

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Now there are some basic properties of a fertile soil. First of all they should be rich in nutrients necessary for basic plant nutrition including nitrogen phosphorous and potassium. They contain sufficient minerals for plant nutrition including boron, chlorine cobalt copper iron manganese magnesium molybdenum sulfur and zinc.

And it they con they generally contains soil organic matter that improves soil structure and soil moisture retention and soil ph is in the range between 6 to 6.8 for most plants. And they these soil should have good soil structure creating well drained soil. The range of microorganisms that supports they should have range of microorganisms that support plant growth. And they should often contain large amount of topsoil. So these are some of the basic properties of a fertile soil.

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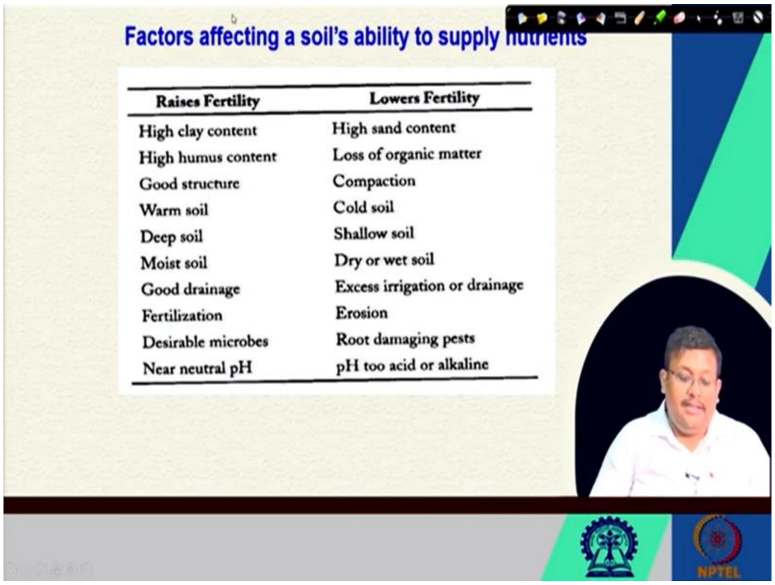

These are some of the factors affecting the soil stability to supply nutrients these are the some of the factors which raise the soil fertility like high clay content high humus content good structure warm soil deep soil moist soil good drainage fertilization desirable microbes and near neutral piece. These are all features which help to raise the soil fertility.

And these are some of the factors which lowers the soil fertility like high sand content loss of organic matter compaction cold soil shallow soil dry or wet soil excess irrigation drainage erosion root damaging paste and ph of acidic and alkaline soil. So if it is too acidic or too alkaline that will also lowers the soil fertility.

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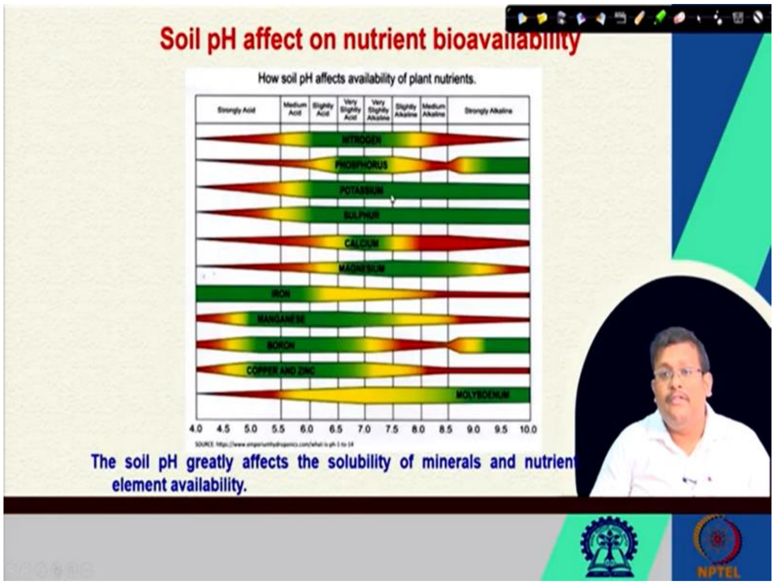

Of course soil ph greatly affects the solubility of the minerals and nutrients element availability. You can see here nitrogen is mostly available in in the near neutral condition just like phosphorous potassium sulphur calcium magnesium. And their availability goes down when the soil becomes strongly acid and strongly alkaline. In case of potassium the alkaline condition we can see potassium and sulfur they are available in alkaline condition.

But in case of calcium magnesium their availability goes down in case of strongly acidic and strongly alkaline condition. In case of micronutrients iron manganese boron copper zinc they are basically available mostly available in medium acidic condition. And their availability goes down in the alkaline condition only exception is molybdenum in which the availability increases with strongly alkaline condition.

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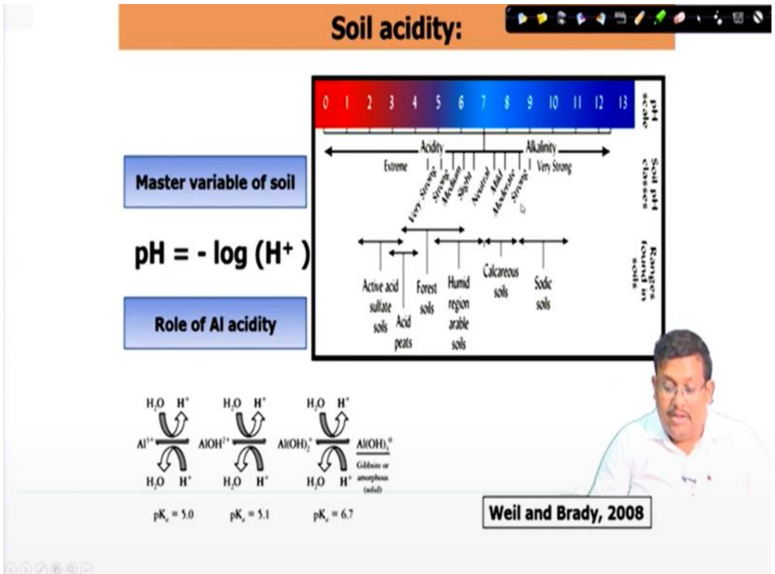

So this is the implication of the soil acidity and alkalinity if the alkalinity is quite high we call it sodic soil. And calculus soils generally have neutral to mild moderate and strong alkalinity. And in the humid region generally we can see formation of soil acid acidic soil and generally forest soils are showing very strong to strong and merit medium and slight acidity.

In case of acid pits we and also active acid sulphate soil we can see active soil extreme soil acidity. We know that ph is negative logarithm of hydrogenated concentration and below ph 5.5 aluminium donates the high hydrogen ion in the soil solution by hydrolysis and thus they contribute towards soil acidity that is why both h plus ion and l three plus ion are considered as acidic.

So here you can see they produce these hydrogen and into the soil solution and as a result they create so toxicity for the root growth. So these aluminum three plus ion is also known as acidic ion apart from this h plus scatter.

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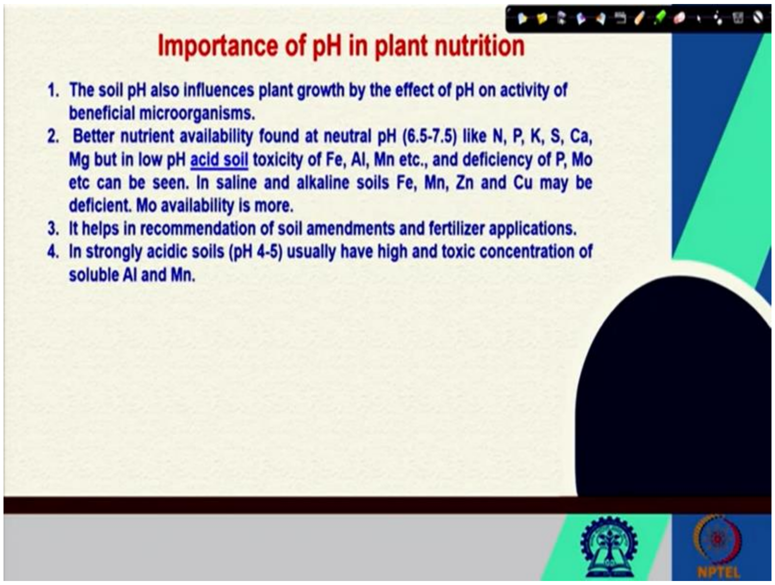

Now let us see the importance of ph in plant nutrition of course the soil ph also influences the plant growth by by the effect of ph on activity of beneficial microorganisms. Better nutrient availability found in at me and neutral ph which is 6.5 to 7.5 like nitrogen phosphorus potassium sulphur calcium magnesium. But in low ph acidic soil toxicity of ion aluminium manganese etcetera and deficiency of phosphorus molybdenum can be seen.

In saline and alkaline soils iron manganese zinc and copper may be deficient and molybdenum availability is more. It helps soil ph helps in recommendation of soil amendments and fertilizer application not only the fertilizer application but also the reclamation of the acidic soil or alkaline soil is important so we have to add some either we have to add lime or gypsum to correct the soil ph because soil ph influences the availability of the nutrients.

In strongly acid soils when it is ph 4.5 they have usually high and toxic concentration of soluble aluminum and manganese.

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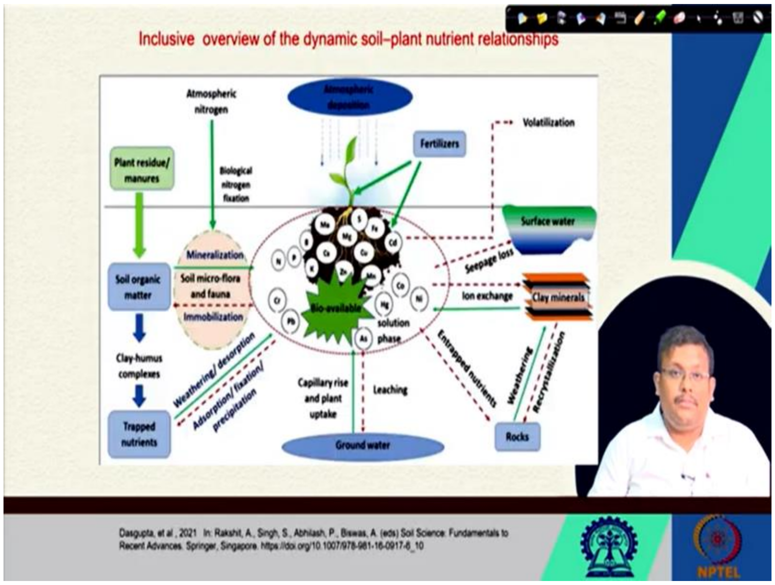

Now this is an inclusive overview of the dynamic soil plant nutrient relationship. Of course when there is an atmospheric nitrogen and that can be fixed to biological nitrogen fixation and plant residues and manure also can produce the soil organic matter. So they ultimately go through mineralization process to soil microflora and fauna.

And the opposite process is immobilization process these are bioavailable nutrients from which plants are uptaking these nutrients through roots. So these are some atmospheric deposition we are also adding fertilizers and these nutrients are basically present in solution phase. So from the soil organic matter we can see the formation of clay humans complexes and this nutrient gets trapped inside this clay humans complex and due to the weathering or disruption process they release into the soil solution.

The opposite process is adsorption or fixation or precipitation when these freely available nutrients became trapped inside this clay humans complex. From these soil solution nutrients they also can leach to the ground water and sometime there is a capillary rise of and plant uptake of these nutrients from the ground water. These nutrients from the soil solution can get entrapped into the rocks and due to the weathering process these nutrients gets released into the clay minerals and in the recrystallization process the clay minerals goes back into the rocks.

From the iron exchange process this nutrient gets exchanged to the nutrients which are present in soil solution. And also these nutrients are removed through seepage loss on the surface water. And some nutrients like nitrogen is also released from the soil to volatilization.

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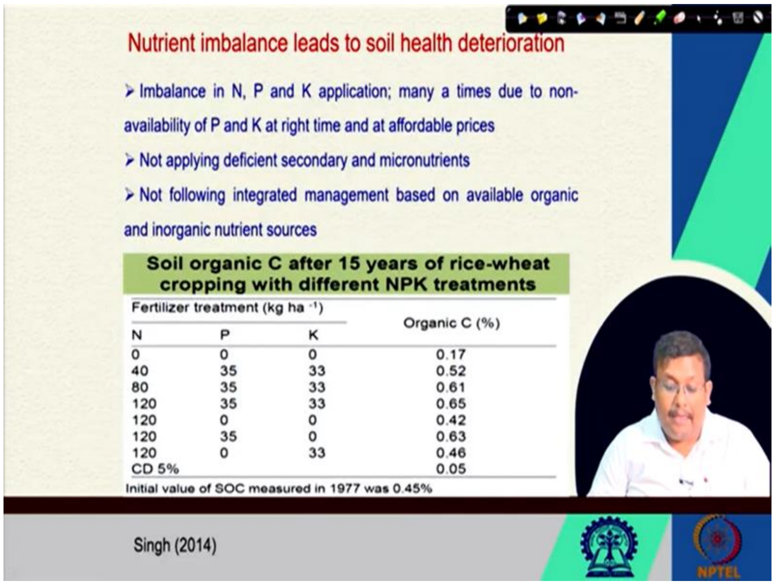

So nutrient imbalance leads to soil health deterioration. So imbalances of nitrogen phosphorus and potassium application many a times due to non-availability of potassium and phosphorous at right time and an affordable prices create this imbalance. And not applying deficient secondary and micronutrients can also create this nutrient imbalance and finally not following integrated management based on available organic and inorganic nutrient sources can also create this nutrient imbalance and health deterioration.

So here you can see when all these three are zero we can see soil organic carbon only 0.717 percent, when they are on equal amount we are getting 0.52 and 1.61 and also 0.65 however when there is an imbalance between these three elements we can see it is further goes down. And so that shows that the balanced fertilization how it is important for the overall soil health and plant nutrition.

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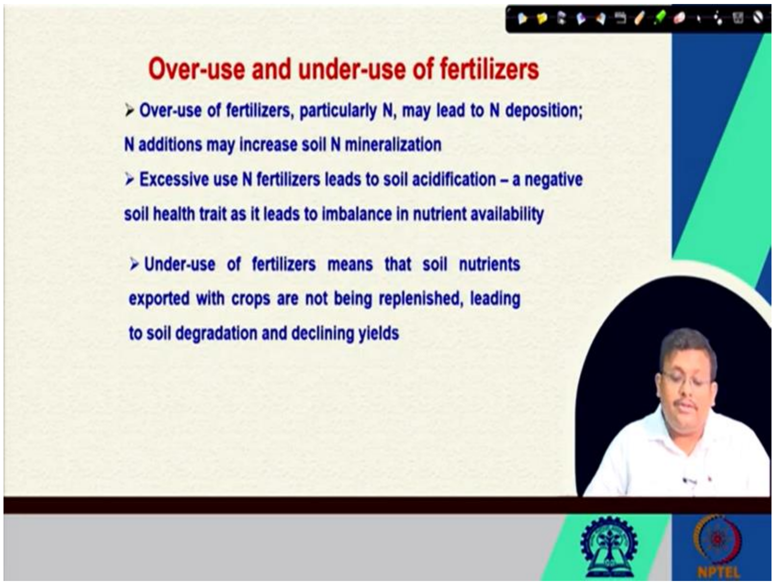

Over use of fertilizers particularly nitrogen may also lead to nitrogen deposition and excessive use of nitrogen fertilizer leads to soil acidification which creates a negative soil health trait as it leads to imbalance in nutrient availability. And under use is another extreme so under use of fertilizer means that soil nutrient exported with crops are not being replenished and leading to soil degradation and declining is.

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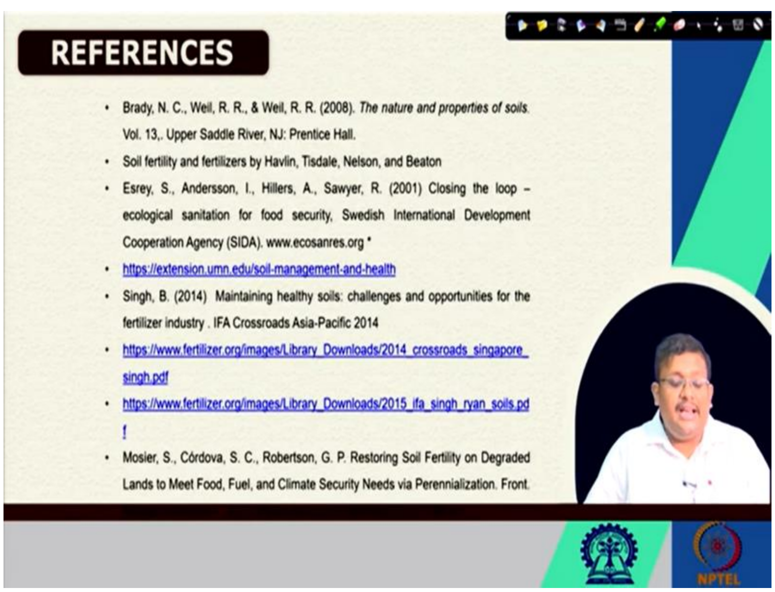

So guys by this have completed these lectures of week one and these are some of the references which I have used in this week lectures. And please feel free to go through this literature and if you have any question just feel free to let me know and I will be more than happy to answer your queries. So these are some of the references.

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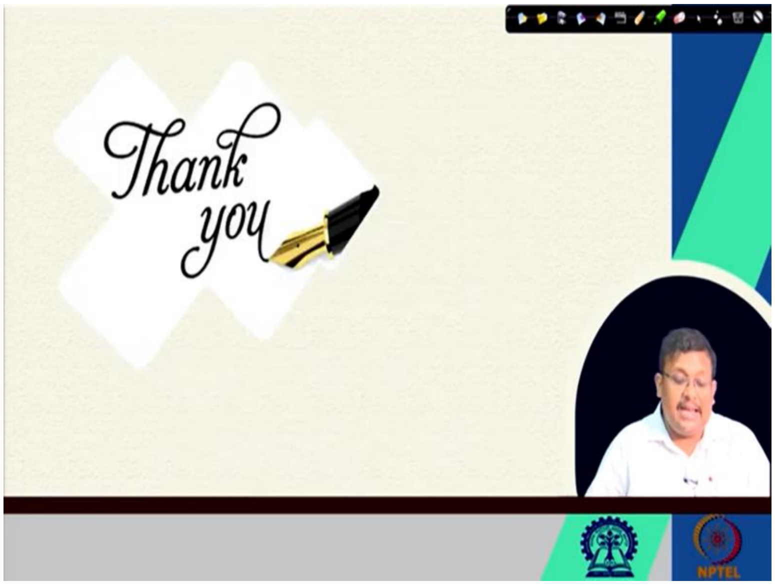

And thank you let us meet in our next week of lectures to discuss some other aspects of plant nutrition. Thank you.